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**BAKER BOTTS LLP**

30 ROCKEFELLER PLAZA  
44TH FLOOR  
NEW YORK, NEW YORK  
10112-4498  
212.705.5000  
FAX 212.705.5020

4  
AUSTIN  
BAKU  
DALLAS  
HOUSTON  
LONDON  
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**NEW YORK**  
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Appln. Trans.  
PATENT

**UTILITY PATENT  
APPLICATION  
TRANSMITTAL**

*(Only for new nonprovisional  
applications under 37 CFR 1.53(b))*

Attorney Docket No. A33341

First Named Inventor Siu Chung Tam

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July 18, 2000

**BY EXPRESS MAIL - Label No. EK839860152US**

Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

Sir:

Enclosed herewith for filing is a patent application of Siu Chung Tam entitled A SEMICONDUCTOR  
PASSIVE Q-SWITCH PROVIDING VARIABLE OUTPUTS

which includes:

<input checked="" type="checkbox"/> Specification	<u>9</u> Total Pages
<input checked="" type="checkbox"/> Claims	<u>2</u> Total Pages
<input checked="" type="checkbox"/> Abstract	<u>1</u> Total Pages
<input checked="" type="checkbox"/> Drawing(s)	<u>6</u> Total Sheets
<u>X</u> formal	
<u>  </u> informal	

☒ Combined Declaration and Power of Attorney **Unsigned**    Total Pages  
☐ Newly executed (original or copy)  
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If a continuing application, check appropriate box:

☐ Continuation ☐ Divisional ☐ Continuation-In-Part (CIP)  
of prior application No.   

☐ Amend the specification by inserting, before the first line, the following sentence:

"This is a ☐ continuation ☐ divisional ☐ continuation-in-part  
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Attorney Docket No. A33341

- ☐ An Assignment of the invention to \_.
- ☐ is attached. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
- ☐ will follow.
- ☐ has been filed in the prior application
- ☐ Small Entity Statement(s) **ENCLOSED**.
- ☐ Small Entity Statement filed in prior application. Status still proper and desired.
- ☐ Information Disclosure Statement (IDS) PTO-1449
- ☐ Copies of IDS Citations.
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- ☒ Return Receipt Postcard
- ☐ Other \_
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The filing fee has been calculated as shown below:

FOR	(Col. 1) No. Filed	(Col. 2) No. Extra	Small Entity Rate	Fee	OR	Other Than A Small Entity Rate	Fee
Basic Fee							\$690.00
Total Claims	16	-20 = 0	x 9 =	\$0.00	x 18 =		\$0.00
Ind. Claims	1	-3 = 0	x 39 =	\$0.00	x 78 =		\$0.00
Multiple Dependent Claim			+ 230 =		+ 260 =		
			Total	<u>\$0.00</u>			<u>\$690.00</u>

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Fee Payment Being Made:

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☒ Basic filing fee \$690.00

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[\$40.00; 37 CFR 1.21(h)]

Total Fees Enclosed \$690.00

☒ A check in the amount of \$690.00 to cover filing fee is enclosed.

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PATENT

Attorney Docket No. A33341

Priority

- ☐ Priority of application Country \_\_, Appln. No. \_\_ filed \_\_ is claimed under 35 U.S.C. 119.
- ☐ Certified Copy of Priority Document(s) Country \_\_, Appln No. \_\_, filed \_\_.
- ☐ is/are attached ☐ will follow ☐ has been filed in the parent application S/N \_\_.
- ☒ The Commissioner is hereby authorized to charge payment of any additional filing fees required under 37 CFR 1.16, 1.17, and 1.21(h) associated with this communication or credit any overpayment to Deposit Account No. 02-4377. Two copies of this sheet are enclosed.

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By

Ronald B. Hildreth

PTO Registration No. 19,498

Enclosures

## A SEMICONDUCTOR PASSIVE Q-SWITCH PROVIDING VARIABLE OUTPUTS

### TECHNICAL FIELD

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This invention relates to passive Q-switching of a laser system. In particular the invention relates to a passive Q-switch that may be used in a laser system to produce laser pulses having variable output characteristics. The Q-switch may include a semiconductor wafer. The output characteristics of the laser pulses may be tuned by changing the transmittance of the wafer. The output characteristics may include pulse duration and pulse repetition rate of the Q-switched laser beam. The same semiconductor wafer may be simultaneously used as the output coupler of the cavity of the laser to render the laser system more compact.

15

### BACKGROUND OF THE INVENTION AND PRIOR ART

Q-switching is a common and effective technique to achieve optical pulses with short duration, high repetition rate and high peak power. These characteristics are required for laser ranging, nonlinear studies, medicine, laser micro-machining, and other important applications. Q-switching can be effected using an active device which is controlled or driven by an external signal. Q-switching can also be performed using a passive structure that has no external control, but instead operates periodically as a result of its own properties. The present invention relates to a laser system using such a passive Q-switching method.

Passive Q-switching employing a saturable absorber as a Q-switch element is economical, simple and practical. There are many different materials and configurations for passive Q-switching.

U.S. Pat. No. 3,997,854 entitled "Passive Q-Switch Cell", issued to Buchman et al, discloses a passive Q-switch cell of a liquid saturable solution of dye used on the laser wavelength of 1.06  $\mu\text{m}$ . U.S. Pat. No. 4,637,030 entitled "Switching Laser", issued to Midavaine et al, discloses a passive Q-switching method with absorption gas used on the laser wavelength of 10.6  $\mu\text{m}$ . U.S. Pat.

No. 5,414,724 entitled "Monolithic Self Q-Switched Laser", issued to Zhou et al, discloses a monolithic self-Q-switched laser with a single Cr:Nd:YAG crystal to generate laser pulses at the wavelength of 1.06  $\mu\text{m}$ . U.S. Pat. No. 5,832,008 entitled "Eyesafe Laser System Using Transition Metal-Doped Group II-VI Semiconductor as a Passive Saturable Absorber Q-Switch", issued to Birnbaum et al, discloses a passive Q-switch element of Co:ZnSe for laser system at the wavelength of 1.54  $\mu\text{m}$  and 1.6  $\mu\text{m}$ . U.S. Pat. No. 5,724,372 entitled "Diode-Pumped Laser System Using Uranium-Doped Q-Switch", issued to Stultz et al, discloses a diode-pumped Er:Yb:Glass laser with an output from about 1.5  $\mu\text{m}$  to 1.6  $\mu\text{m}$  and Q-switched with U:CaF<sub>2</sub>. U.S. Pat. No. 5,802,083 entitled "Saturable Absorber Q-Switches for 2- $\mu\text{m}$  Laser", issued to Birnbaum et al, discloses a passively Q-switched laser with an output from about 1.6  $\mu\text{m}$  to 2.3  $\mu\text{m}$  using Ho:YLF or Ho:YVO<sub>4</sub> as Q-switch material. U.S. Pat. No. 5,237,577 entitled "Monolithically Integrated Fabry-Perot Saturable Absorber", issued to Keller et al, discloses a Fabry-Perot saturable absorber with a construction of multiple quantum well of AlAs/GaAs, which can be used as a saturable absorber in passive Q-switching and passive modelocking. It was also used as the end mirror of a diode-end-pumped Nd:YLF laser.

Active Q-switching allows a user to vary the output characteristics of a laser beam. A major disadvantage of passive Q-switching, as compared to active Q-switching, is non-adjustability of the parameters of the Q-switched pulses. There is no effective way to control or adjust the parameters of passive Q-switching. It would be useful to devise a technique that is capable of adjusting the parameters of passively Q-switched pulses using a single saturable absorber in the laser cavity.

Saturable absorbers are known to be key elements for passive Q-switching. Materials such as solids, liquids and gases have been used as saturable absorbers based upon the chosen wavelength of laser operation. Generally, the theoretically shortest pulse duration achievable from a Q-switched laser system is limited by the round-trip time of the laser cavity. The shorter the laser cavity, the shorter the Q-switched pulse duration. Therefore shortening the laser cavity is an effective way to get shorter pulses.

Existing Q-switches are mainly made of active devices that make use of acousto-optic or electro-optic effects. These Q-switches require drivers to

operate. It would be desirable to provide a tunable passive Q-switch that is a simple device requiring no external drivers and hence may offer reduced operating costs and can render a laser resonator very compact.

Kajava et al [Optics Letters, 21(6), 1996] use a piece of GaAs wafer inside the cavity of an end-pumped Nd:YAG laser to achieve passive Q-switching. The GaAs wafer has a fixed transmittance value. By changing the pump power, the output characteristics of the laser, such as the pulse repetition rate and pulse duration, will vary. However, there are disadvantages in using pump power as the control variable as the emission wavelength of the diode laser may drift away from its optimum value, the temperature of the diode laser may take a long time to stabilise, and the beam quality of the Nd:YAG laser output may change substantially.

Through experimental and theoretical studies [J. H. Gu, et al, *SPIE* Vol. 3398, pp.170-177, November 1999], it is found that the GaAs wafers used for passive Q-switching may exhibit Fabry-Perot (F-P) effect. Furthermore, effective transmittance of a GaAs wafer, which is generated by this F-P effect, could create a large impact on the output characteristics of the passively Q-switched laser. Based on this prior art, further improvements were made and the following details the improvements.

## SUMMARY OF THE INVENTION

The current invention is conceptualized based on this new development. By applying gradient coating on a single piece of GaAs wafer, the effective transmittance of the GaAs wafer can be varied. Therefore, using a single piece of gradient coated GaAs wafer, the laser output characteristics of the GaAs Q-switch, operating at a fixed pump power, can be varied. This improvement avoids the many disadvantages of using pump power as the variable parameter in changing the laser output characteristics.

According to the present invention there is provided a semiconductor passive Q-switch providing variable output suitable for use in a laser system to produce laser pulses having defined output characteristics including a lasing wavelength, said Q-switch including variable transmittance means at the lasing wavelength for adjusting said output characteristics of said laser pulses.

Typically, the laser system may employ a Nd:YVO<sub>4</sub> crystal lasing at the wavelength of 1.06  $\mu\text{m}$  with a diode laser used as the pumping source at the wavelength of 808 nm. A piece of undoped semiconductor wafer may serve as a Q-switch. This wafer may also serve as the output coupler of the laser cavity.

5 One advantage of employing such a construction is that there is no need to insert extra elements into the laser cavity as a Q-switch element or as an output coupler, so that the length of the laser cavity can be shortened, and consequently shorter-duration Q-switched pulses can be obtained.

The Q-switch may include a wafer of GaAs. The surface of the GaAs  
10 wafer may be coated so that the transmittance varies for different parts of the wafer. Variations can be effected in a stepwise manner, such that different patches of the wafer may give different transmissions. The variation can also be effected in a gradual manner along a linear length of the wafer, or along a curvilinear path on the wafer. The parameters of the Q-switched laser pulses  
15 may be adjusted by moving the wafer with respect to the axis of the laser cavity.

Typically, the Q-switch utilizes a piece of undoped GaAs wafer, which has the characteristics of saturable absorption, in the spectrum of the IR range. Other doped and undoped semiconductors with the property of saturable absorption, such as AlGaAs, InP, InGaAs, etc., can be used as the Q-switch element in this  
20 technique. Multiple-quantum-well semiconductor structures are also suitable candidates.

The device can be applied to Q-switched solid-state lasers for scientific and technological applications such as micro-machining (e.g. sensors and actuators, laser cleaning of hard discs, etc.), micro-fabrication (microlithography,  
25 laser assisted thin film deposition, etc.), biomedical studies (tattoo removal, dental treatment, etc.), etc.

## BRIEF DESCRIPTION OF THE DRAWINGS

30 A preferred embodiment of the present invention will now be described with reference to the accompanying drawings wherein:

FIG. 1 is a schematic drawing of a laser system that utilizes the present invention;

FIG. 2a shows a typical measured transmission distribution curve of the passive Q-switch shown in FIG. 1, using a piece of graded GaAs wafer as the tunable element at the wavelength of 1.06  $\mu\text{m}$ ;

FIGs. 2b(i) to 2b(iv) show typical patterns and structure for the passive Q-switch;

FIG. 3 shows typical measured results of variations of pulse duration and pulse repetition rate of the Q-switched pulses when the wafer is adjusted along its length direction, while keeping all other operating conditions of the laser system unchanged;

FIG. 4 shows typical measured results of variations of averaged power and peak power of the Q-switched output pulses when moving the wafer along its length direction, while keeping all other operating conditions of the laser system unchanged; and

FIG. 5 shows a typical oscilloscope trace of a laser pulse as a function of time for the laser system of FIG. 1, using a GaAs wafer as a Q-switch as well as an output coupler of FIG. 2a.

## DETAILED DESCRIPTION OF THE INVENTION

FIG.1 illustrates schematically the use of a semiconductor wafer in a laser system including a pumping source **10**, a beam shaping system **20**, a laser gain material **30**, and a passive Q-switch **40**, which also serves as the output coupler for the laser system. In an alternative embodiment, the tunable passive Q-switch may not operate simultaneously as the output coupler of the laser system. In such a case, in line with common practice in the trade, a partially transmitting mirror at the laser wavelength may be used as the output coupler.

The pumping source **10** consists of a diode laser **11** and delivery optical fiber **12**, providing a pumping laser beam **13**, which has a center wavelength matching the absorption peak of the laser crystal **32**. The laser beam **13** is collimated by a first lens **21** and then focused by a second lens **22** to a laser crystal **32**. The laser crystal **32** is 1% (by atomic weight) doped Nd:YVO<sub>4</sub>, with one facet **31** anti-reflection (AR) coated at the wavelength of 808 nm and high-reflection (HR) coated at the wavelength of 1.06  $\mu\text{m}$  and serving as a total reflection mirror of the laser cavity, and another facet **33** AR coated at the



wavelength of 1.06  $\mu\text{m}$ . Element **40** includes a piece of semiconductor wafer **41**, which is coated gradually on its surface **42** and/or surface **43**, and a miniature translation stage **44**, on which element **41** is mounted. Element **40** serves as a passive Q-switch as well as the output coupler of the laser cavity.

5 In other embodiments, the end-pumping geometry may be altered or simplified. In yet other embodiments, the laser medium **30** may be pumped by the diode laser **10** from the side, or may be pumped simultaneously from the end and by the side.

FIG.2a shows details of an example of the Q-switch element **40**. The  
10 element **40** is a piece of undoped GaAs wafer with a dimension of 20 mm in length, 10 mm in width and 625  $\mu\text{m}$  in thickness. Its two faces are optically polished, and both of its two surfaces are gradually coated with AR coating. The curve in FIG. 2a indicates the measured distribution of transmission at the wavelength of 1.06  $\mu\text{m}$  in the direction along the length of the wafer. It has a  
15 homogenous transmission distribution in the direction along the width of the wafer.

In other embodiments, one side of the wafer may be coated to provide variable transmission, and the other side of the wafer may be uncoated. In yet other embodiments, discrete patches giving different transmittance values may  
20 be used instead of a graded structure, or variation of transmittance may be effected by rotation instead of linear translation. Variable transmittance may also be effected by using a semiconductor with variable thickness, e.g., a wedge. Typical patterns and structures for element **41** are shown in FIGs. 2b(i) to 2b(iv).

In FIG. 2b(i), element **411** represents a rectangular structure of element  
25 **41** with a gradient distribution of transmittance and in Fig.2(b)(ii) element **412** represents a rectangular structure of element **41** but with a discrete distribution of transmittance. In Fig.2b(iii) element **413** represents a circular structure of element **41** with a gradient or discrete azimuthal distribution of transmittance and in Fig.2b(iv) element **414** represents a wedged structure of element **41**, having a  
30 different transmittance at each different thickness.

One theory of using a semiconductor material for passive Q-switching is presented herein. More detailed descriptions can be found in J.H. Gu et al (*Optical Engineering*, 38 (11), pp. 1785-1788 (1999)). The bandgap of GaAs is 1.42 eV and the photon energy of the laser radiation at the wavelength of 1.06

$\mu\text{m}$  is 1.17 eV. Therefore, there is no band-to-band absorption occurring at this wavelength. However, because the EL2 defect energy level is 0.82 eV below the conduction band, GaAs exhibits saturable absorption characteristics at the wavelength of around 1.0  $\mu\text{m}$ , mainly contributed by processes of two-photon-absorption and free-carrier-absorption. The property of saturable absorption makes GaAs a good candidate to be used as a saturable absorber in a laser cavity to perform passive Q-switching.

Q-switching is accomplished by making the cavity loss an explicit function of photon density, as in the case of the passive Q-switching by saturable absorption of GaAs. In the present invention, element **40** provides both saturable loss as a saturable absorber and coupling loss as an output coupler of the laser cavity. The parameters of passively Q-switched laser pulses, such as pulse duration, pulse repetition rate, peak power, and averaged output power, are determined by the loss property of the laser cavity.

According to conventional rate equations which can be used to describe the output characteristics of Q-switched operation, it is well known that under a certain pumping condition, the loss of the laser cavity will be a unique parameter determining photon density inside the laser cavity and population inversion density within the laser gain material. Therefore, the parameters of the Q-switched laser pulses can be adjusted by changing the loss property of the laser cavity. This makes it possible to improve a major disadvantage of passive Q-switching, namely its general inability to provide adjustability to its output characteristics.

In the present invention, adjusting translation stage **44** to move element **40** with properties as indicated in FIG. 2a along its length, will change the transmission of the output coupler as well as the loss properties of the laser cavity. Therefore, the parameters of the passively Q-switched laser pulses can be adjusted continuously or discretely.

FIG. 3 shows a typical result of variations of measured pulse duration and pulse repetition rate from the laser system shown in FIG. 1 at different locations when the element **40** is moved from one end to the other. Pulse duration increases from 5.7 ns to 14.5 ns and the corresponding pulse repetition rate increases from 250 kHz to 1.0MHz when the distance to the edge with low transmission is increased from 4 mm to 16 mm, while keeping all other

parameters of the laser operation unchanged: the beam power of the pumping diode laser is 3.9 W at the wavelength of 808 nm; the laser crystal **32** has a dimension of 3 mm × 3 mm × 5 mm; the gap between the GaAs wafer **41** and the laser crystal **32** is 1 mm; and the physical length of the laser cavity is 6 mm.

5 During adjustment, the transmittance of element **40** increases from 4.8 % to 45.6 % as shown in FIG. 2a.

FIG. 4 shows the variation of measured averaged output power and peak power from the passively Q-switched laser system of FIG.1 operating with the same settings described above. The average output power increases from 0.17 W to 0.4 W when the transmittance increases from 4.8 % to 45.6 %.

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In another embodiment, the shortest pulse duration obtained from the passively Q-switched laser system is 1.6 ns. This is evident from the oscilloscope trace of the temporal development of a laser pulse shown in FIG.5. The results are obtained with element **40** being a piece of GaAs wafer with a thickness of 625 μm and with one side uncoated and the other side coated to form a gradient transmission profile. The measured output characteristics of the passively Q-switched pulses have similar tuning capabilities as described above by adjusting the position of element **40** in FIG.1.

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The present invention may thus provide a means of passively Q-switching a laser system with a variable transmittance semiconductor wafer as a Q-switch element. The wafer can double-up as an output coupler. Using this device, the operating characteristics of the passively Q-switched laser pulses can be adjusted by changing the location of the wafer while keeping the laser operating parameters unchanged. Such characteristics include the pulse duration, pulse repetition rate, and output power of the laser beam.

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Although the present invention has been described with reference to a particular embodiment, viz. a diode-pumped solid-state laser, it will be apparent to persons skilled in the art that the present invention may be applied to other kinds of solid-state lasers, such as lamp-pumped solid-state lasers, and suitable lasers in general. Furthermore, the present invention can also be used for other IR wavelengths because certain types of semiconductor materials and bandgap-engineered materials have the properties of both saturable absorption, which is required as a passive Q-switch, and partial transmission in the IR spectrum which is required as an intracavity element or as an output coupler.

30

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

**Claims**

- 5 1. A semiconductor passive Q-switch providing variable outputs suitable for use in a laser system to produce laser pulses having defined output characteristics including a lasing wavelength, said Q-switch including variable transmittance means at the lasing wavelength for tuning said output characteristics of said laser pulses.
- 10 2. A semiconductor Q-switch according to claim 1 wherein said output characteristics include pulse duration, pulse repetition rate, peak power and averaged output power of said laser pulses.
- 15 3. A semiconductor Q-switch according to claim 1 wherein said variable transmittance means includes a wafer having two surfaces that are optically polished, one or both surfaces being optically coated to form a gradient variation of transmission at a wavelength substantially in the IR region.
- 20 4. A semiconductor Q-switch according to claim 3 wherein said surfaces are optically coated to form a gradient variation of transmission at a wavelength in the IR region.
5. A semiconductor Q-switch according to claim 1 wherein said variable  
25 transmittance means includes a material having variable thickness, such as a wedge.
6. A semiconductor Q-switch according to claim 1 wherein tuning of said output characteristics is effected by translating the Q-switch.
- 30 7. A semiconductor Q-switch according to claim 1 wherein tuning of said output characteristics is effected by moving the Q-switch in a curvilinear path.
8. A semiconductor Q-switch according to claim 7 wherein said curvilinear  
35 path includes circular rotation.

9. A semiconductor Q-switch according to claim 1 wherein said Q-switch functions simultaneously as an output coupler of said laser system.

5 10. A semiconductor Q-switch according to claim 1 including undoped GaAs.

11. A semiconductor Q-switch according to claim 1 including doped or undoped semiconductor material having properties of saturable absorption in the IR spectrum.

10

12. A semiconductor Q-switch according to claim 11 wherein said semiconductor material includes AlGaAs or InP.

15

13. A semiconductor Q-switch according to claim 1 having a multiple-quantum-well configuration.

20

14. A laser system incorporating a semiconductor passive Q-switch according to claim 1, said laser system including a solid-state laser that is diode-end-pumped, diode-side-pumped, hybrid-pumped, lamp-pumped or pumped with other lasers.

25

15. A laser system incorporating a semiconductor passive Q-switch according to claim 1 and adapted to produce a laser output at a wavelength centered at an IR wavelength.

16. A laser system according to claim 15 wherein said IR wavelength is substantially  $1.06\mu\text{m}$ .

## **A SEMICONDUCTOR PASSIVE Q-SWITCH PROVIDING VARIABLE OUTPUTS**

5

### **ABSTRACT**

A semiconductor wafer with variable transmittance, serves as a saturable absorber for performing passive Q-switching in a laser system to produce laser pulses having defined output characteristics. By translating or rotating the semiconductor saturable absorber, loss properties of a laser cavity may be altered. In this manner, the output characteristics of the laser pulses can be varied without changing other parameters of laser operation. The output characteristics may include pulse duration, pulse repetition rate, peak power and average output power of the laser pulses. The semiconductor wafer can be made of doped or undoped GaAs, AlGaAs, InP, etc. Furthermore, the tunable Q-switch may simultaneously serve as an output coupler for the laser cavity.

FIG. 1

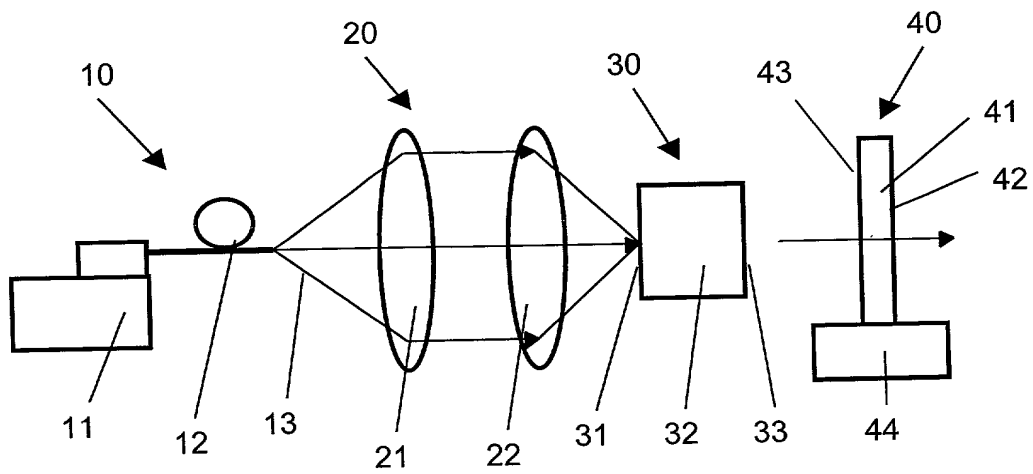
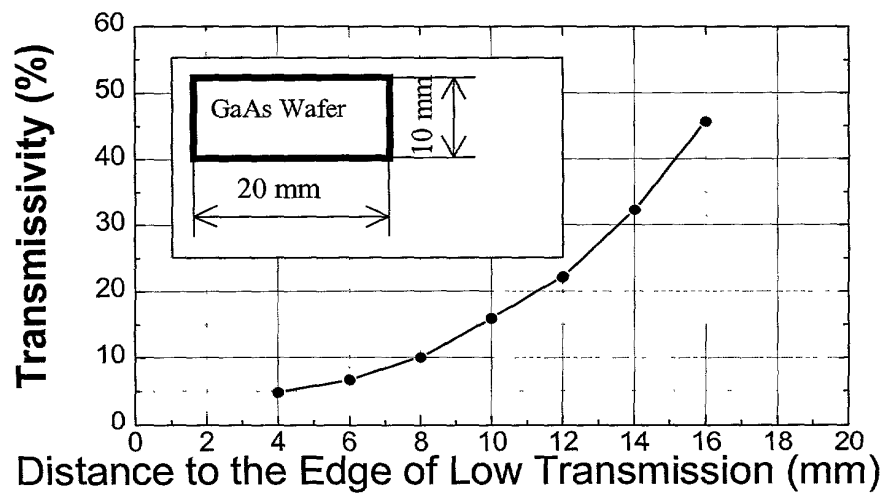




FIG. 2a



**FIG. 2b**

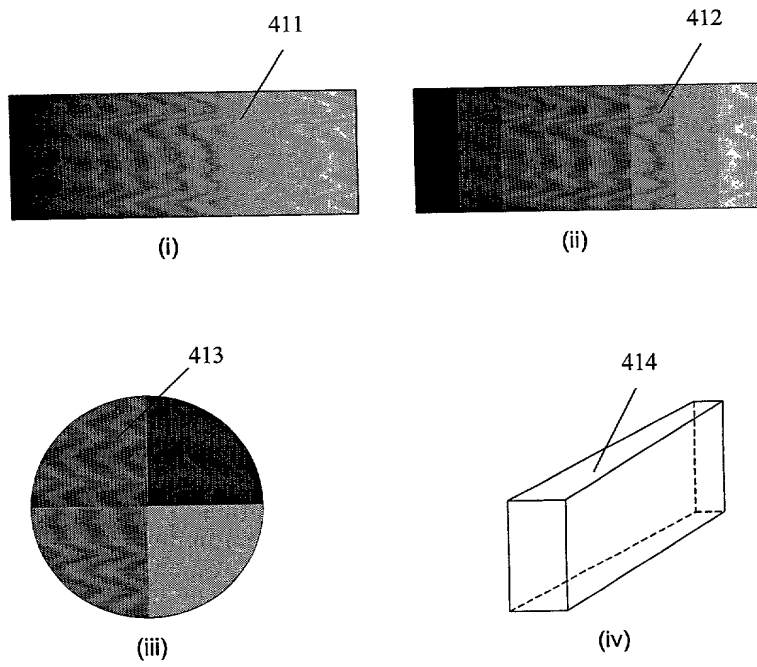


FIG.3

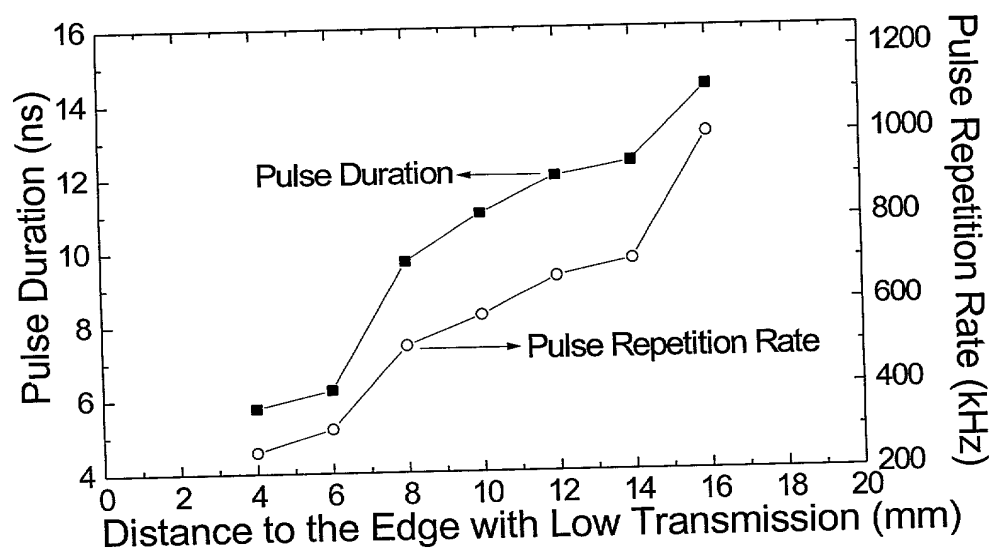


FIG.4

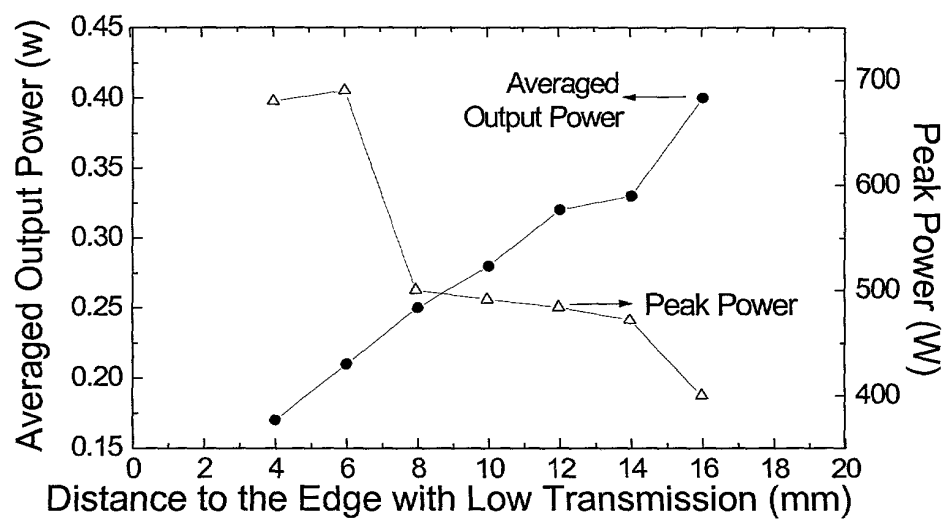
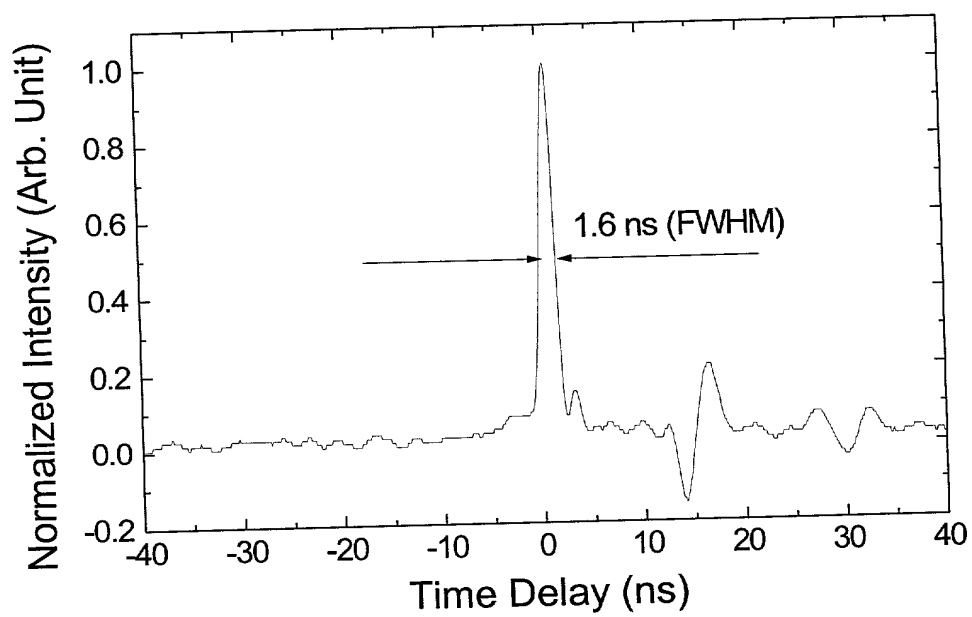


FIG.5



**COMBINED DECLARATION  
AND POWER OF ATTORNEY**

**(Original, Design, National Stage of PCT, Divisional, Continuation or C-I-P Application)**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

A SEMICONDUCTOR PASSIVE Q-SWITCH PROVIDING VARIABLE OUTPUTS

This declaration is of the following type:

- ☒ original  
☐ design  
☐ national stage of PCT.  
☐ divisional  
☐ continuation  
☐ continuation-in-part (C-I-P)

the specification of which: *(complete (a), (b), or (c))*

(a) ☐ is attached hereto.

(b) ☐ was filed on as Application Serial No. and was amended on *(if applicable)*.

(c) ☐ was described and claimed in PCT International Application No. filed on and was amended on *(if applicable)*.

**Acknowledgement of Review of Papers and Duty of Candor**

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of the subject matter claimed in this application in accordance with Title 37, Code of Federal Regulations § 1.56.

☐ In compliance with this duty there is attached an information disclosure statement. 37 CFR 1.98.

**Priority Claim**

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT International Application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT International Application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application on which priority is claimed

*(complete (d) or (e))*

(d) ☐ no such applications have been filed.

(e) ☐ such applications have been filed as follows:

PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION			
COUNTRY	APPLICATION NO.	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)
			PRIORITY CLAIMED UNDER 35 USC 119 <input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
ALL FOREIGN APPLICATION[S], IF ANY, FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION			
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>

### Claim for Benefit of Prior U.S. Provisional Application(s)

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

Provisional Application Number	Filing Date

### Claim for Benefit of Earlier U.S./PCT Application(s) under 35 U.S.C. 120

*(complete this part only if this is a divisional, continuation or C-I-P application)*

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
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(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
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### Power of Attorney

As a named inventor, I hereby appoint Dana M. Raymond, Reg. No. 18,540; Frederick C. Carver, Reg. No. 17,021; Francis J. Hone, Reg. No. 18,662; Joseph D. Garon, Reg. No. 20,420; Arthur S. Tenser, Reg. No. 18,839; Ronald B. Hildreth, Reg. No. 19,498; Thomas R. Nesbitt, Jr., Reg. No. 22,075; Robert Neuner, Reg. No. 24,316; Richard G. Berkley, Reg. No. 25,465; Richard S. Clark, Reg. No. 26,154; Bradley B. Geist, Reg. No. 27,551; James J. Maune, Reg. No. 26,946; John D. Murnane, Reg. No. 29,836; Henry Tang, Reg. No. 29,705; Robert C. Scheinfeld, Reg. No. 31,300; John A. Fogarty, Jr., Reg. No. 22,348; Louis S. Sorell, Reg. No. 32,439; Rochelle K. Seide Reg. No. 32,300; Gary M. Butter, Reg. No. 33,841; Marta E. Delsignore, Reg. No. 32,689; and Lisa B. Kole, Reg. No. 35,225 of the firm of BAKER BOTTS L.L.P., with offices at 30 Rockefeller Plaza, New York, New York 10112, as attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith

SEND CORRESPONDENCE TO: BAKER BOTTS L.L.P. 30 ROCKEFELLER PLAZA, NEW YORK, N.Y. 10112 CUSTOMER NUMBER: 21003	DIRECT TELEPHONE CALLS TO: BAKER BOTTS L.L.P. (212) 705-5000
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge

that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR FIRST INVENTOR	LAST NAME TAM	FIRST NAME Siu	MIDDLE NAME Chung	
RESIDENCE & CITIZENSHIP	CITY Singapore	STATE or FOREIGN COUNTRY Singapore, R.O.C.	COUNTRY OF CITIZENSHIP Singapore	
POST OFFICE ADDRESS	POST OFFICE ADDRESS 78-B Eng Kong Place	CITY Singapore	STATE or COUNTRY Singapore, R.O.C.	ZIP CODE 639798
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF SECOND JOINT INVENTOR, IF ANY	LAST NAME GU	FIRST NAME Jian	MIDDLE NAME Hui	
RESIDENCE & CITIZENSHIP	CITY Singapore	STATE or FOREIGN COUNTRY Singapore, R.O.C.	COUNTRY OF CITIZENSHIP Singapore	
POST OFFICE ADDRESS	POST OFFICE ADDRESS Block 831 Jurong West Street 81 #09-256	CITY Singapore	STATE or COUNTRY Singapore, R.O.C.	ZIP CODE 640831
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF THIRD JOINT INVENTOR, IF ANY	LAST NAME LAM	FIRST NAME Yee	MIDDLE NAME Loy	
RESIDENCE & CITIZENSHIP	CITY Singapore	STATE or FOREIGN COUNTRY Singapore, R.O.C.	COUNTRY OF CITIZENSHIP Singapore	
POST OFFICE ADDRESS	POST OFFICE ADDRESS Block 271 Choa Chu Kang Avenue 2 #14-261	CITY Singapore, R.O.C.	STATE or COUNTRY Singapore, R.O.C.	ZIP CODE 680271
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF FOURTH JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME	
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP	
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF FIFTH JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME	
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP	
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE
DATE	SIGNATURE OF INVENTOR			
FULL NAME OF SIXTH JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME	
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP	
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY	ZIP CODE